Lit. Review 3: Topic Summary

Topic: Characterization of context in barking and growling behaviour of the domestic dog (*Canis familiaris*)

Vocalization behavior in mammals has been deeply studied throughout history and yielded several fascinating patterns and trends (Farago et al., 2010). However, one of the most misunderstood vocalizations occur in seemingly one of the most understood species, the domestic dog (*Canis familiaris*) (Yin, 2002). Thousands of years of domestication was thought to have eliminated all communicative function of the barking behaviour of the domestic dog (Yin, 2002). Literature has since corrected this misconception (Yin, 2002). Now, centuries of domestication are thought to have exponentially increased the number of unique contexts in which barking and growling can be observed (Yin, 2002). In fact, researchers analyzed the acoustic features of the vocalizations such as mean frequency and duration of the vocalization period under different situational contexts, and found that during a situation of disturbance, vocalizations had a lower frequency and a longer overall barking period (Yin, 2002). This significant variation indicates that vocalization may vary based on context and situation, thereby insinuating that there is in fact communication occurring through these vocalizations (Yin, 2002).

Many other acoustic parameters such as rate of the vocalization, pitch, time between barks (inter-bark interval) and more can vary considerably across several different contexts and have been used in some fashion to accurately estimate the context of the vocalization (Yin & McCowan., 2004; Pongracz et al., 2006; Taylor et al., 2009b). Features of this type are typically studied experimentally by manipulating context and observing/listening or by recording the behaviour (Pongracz et al., 2009). The most common contexts that generate most variation in behaviour are isolation/abandonment, ball play, dog/human play, feeding, walking, fighting, stranger and disturbance (Larranaga et al., 2014; Pongracz et al., 2009; Pongracz et al., 2006; Yin & McCowan, 2004).

There are many things that can modulate the context specificity and communicative function of vocalization in the domestic dog today. The large anatomical diversity between breeds certainly influence the types of messages that can be communicated (Riede & Fitch, 1999). Researchers studying how anatomical diversity alters the acoustic parameters measured the length of the vocal tract (VTL), where vocalizations are produced, and recorded the vocalizations of dogs from different breeds (Riede & Fitch, 1999). They found that VTL changed inversely with the frequency of vocalizations, and also increased with the size of the sender (Riede & Fitch, 1999). This indicates that the anatomical diversity resulting from evolution could've led to variation in the acoustic parameters modulating context specificity, and also that the frequency of the vocalization may have a role in communicating things like body size (Riede & Fitch, 1999; Taylor et al., 2009a; Farago et al., 2010). In fact, multiple studies have found that information about body size is encoded in the *formant* peak, which is the highest frequency peak generated by a vocalization (Riede & Fitch, 1999; Taylor et al., 2009a; Taylor et al., 2009b). Researchers studied whether the formant frequency is interpreted by dogs as a size cue by exposing dogs to recordings of growls with intentionally doctored formant peaks simulating the growls of dogs of varying sizes (Taylor et al., 2009a). The results showed that large dogs were

more inclined to illicit an immediate aggressive/territorial response when they heard the recording of dogs smaller than themselves (Taylor et al., 2009a). This potentially indicates that not only are dogs able to accurately interpret body size from vocalizations, but they are also able to make immediate behavioural decisions in response to this interpretation, indicating potential neurological influence (Taylor et al., 2009a).

Recently, novel techniques are being employed to study contextual variation in dog vocalizations. Presently, automated algorithms are being developed for this purpose and they have shown remarkable promise in discerning context and even age from vocalizations (Larranaga et al., 2014). However, there are issues with accuracy and reliability of results that prevent it from becoming a staple in the field (Gutierrez-Serrafin et al., 2019). Through reviewing these topics, it's become evident that machine learning is the future of rapidly studying vocalizations and discerning context, so developing this technique more should be prioritized. There also seems to be a lack of literature in the cellular, molecular and genetic influence on vocalization behaviour in dogs so future projects should target this as well.

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